Generally regarded as one of the Nearctic species of *Calidris, bairdii* has a known breeding range through Arctic North America west to the Chukotskiy Peninsula in N.E. Siberia. There is no known wintering area in the Palaearetic or Oriental regions, so the Siberian birds must be presumed to migrate across the Bering Sea to winter in South America, as does the bulk of the Nearctic population. If birds found in Australia are of an easterly origin, then there may be an undiscovered passage of some Siberian birds through eastern Asia. Alternative westerly origins for Australian birds are more awe-inspiring, with vagrants arriving through Europe and southern Asia or otherwise by the southern oceans from South America. Even this last course might not be impossible for a long-winged wader which crosses the north Atlantic to western Europe nowadays with annual regularity (Smith *et al.*, 1972-77).

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THE DISTRIBUTION OF *THEBA PISANA* ON ROTTNEST ISLAND

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The Mediterranean snail, *Theba pisana* (Müller), was introduced on Rottnest Island between 1925 and 1927, in the vicinity of the Settlement. Surveys in 1936, 1947 and 1958 (Serventy, 1949; Serventy and Storr, 1959) documented the expansion of this colony, and the establishment of three isolated colonies at the lighthouse, Cape Vlaming, and Stark Bay. We report here the results of a fourth survey, made in June, September, and December, 1978.

PRESENT DISTRIBUTION

The present distribution of *Theba* on the island is compared with that in 1958 on the accompanying map, and the areas occupied by each colony are shown in Table 1. In the eastern zone, there has been virtually no extension north of Lake Bagdad or south of Government House Lake. The western edge of Point Clune is now occupied, but this is not a recent extension, as G. M. Storr found colonies there in November, 1959 (personal communication). Between the lakes, there has been some westward expansion, and the eastern colonies are now connected with those expanding from the lighthouse. The area south of Gun Hill has many dead shells, but no extant colonies, indicating colonisation and subsequent extinction. An isolated colony at The Bluff is presumably a relict of that expansion.

TABLE 1.—AREAS (IN HECTARES) OCCUPIED BY *THEBA PISANA* ON ROTTNEST ISLAND AT TIMES OF SURVEYS. DATA PRIOR TO 1978 ARE FROM SERVENTY AND STORR (1959).

	1936	1947	1958	1978
Eastern Zone	69	231	358	484
Lighthouse	—	4	59	152
Cape Vlaming	—	6	51	24 (+5)*
Stark Bay	—	—	4	22

* Colony at Marjorie Bay in parentheses.

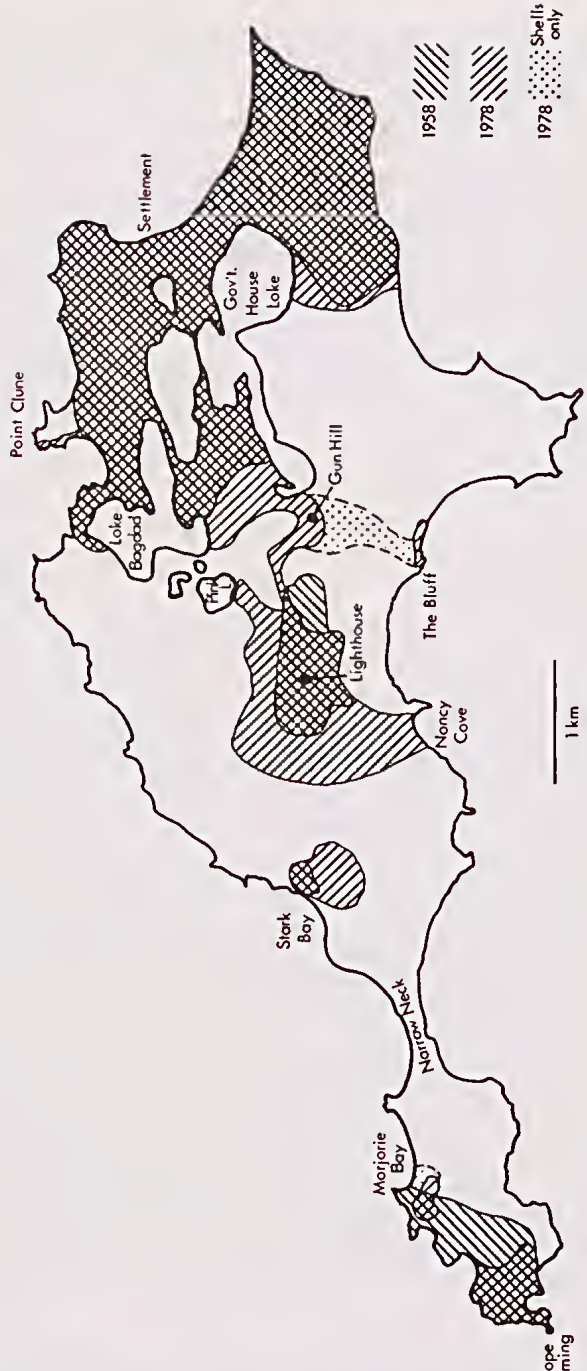

Fig. 1.—Map of Rottnest Island, comparing the distributions of *Theba pisana* in 1978 and 1958.

The greatest expansion has been from the lighthouse. The occupied area now extends to Pink Lake in the northeast, and Nancy Cove in the southwest. Interestingly the limit of distribution immediately south of the lighthouse has been stable for 20 years.

The colonies at Stark Bay and Cape Vlaming remain isolated. The Stark Bay colony has continued to expand, but at Cape Vlaming the snails have retracted westward, leaving an isolate at Marjorie Bay.

DETERMINANTS OF DISTRIBUTION

The most obvious potential determinants of the distribution of *Theba* are suitability of the habitat, effects of fire, and dispersal of the snails. Each of these help to explain the present distribution of *Theba* on Rottnest.

(a) Vegetation

Theba are most common in stands of *Acanthocarpus preissii* and areas with the introduced *Asphodelus fistulosus* (onion weed) and *Trachyandra divaricata*. The areas of expansion from the lighthouse and Stark Bay are covered primarily by these plants.

In contrast *Theba* has not successfully colonised dense stands of *Olearia axillaris* on Rottnest. This is most striking south of the lighthouse, where the change from *Acanthocarpus* to *Olearia* is abrupt, and coincides with the stable boundary of *Theba* occupation. Similarly *Theba* is not found in the *Olearia* stands east of the lighthouse (northeast of Lighthouse Swamp), near Bulldozer Swamp (north of Gun Hill), south of Government House Lake, or in the centre of Point Clune, and is only in the margin of the stand at the west end of Marjorie Bay. South of the lighthouse a few defunct small colonies were found in the *Olearia* area, indicating that this habitat had been invaded, but has not sustained a permanent population.

Although *Olearia* appears not to provide suitable habitat for *Theba* on Rottnest, the reason is not clear. Colreavy (1977) found that *Theba* readily eat *Olearia* leaves. In addition in the sparse stand occupied by the western edge of the Marjorie Bay colony *Olearia* bushes appear to be preferred resting sites for adult snails. Consequently *Theba* do not have an aversion to *Olearia*, and the unsuitability of this habitat may not be due to the plant itself.

The other conspicuous habitat not occupied by *Theba* is mature plantations with much shade and little ground vegetation. For example the snails do not occupy the tuart plantation north of Gun Hill, nor the plantations east of the lighthouse. Similarly, the southwestern edge of the Stark Bay colony abuts on a dense stand of *Acacia*. Such an inhibiting effect is also evident on Garden Island, where *Theba* are very abundant in the firebreaks, but absent from the adjacent *Acacia* thickets.

(b) Fire

Since *Theba* remain above ground throughout the year, they are particularly vulnerable to fire. A major fire burned the area westward from Narrow Neck in 1974, and apparently caused the reduction in the Cape Vlaming colony. The previously occupied area is profuse with charred stumps and dead *Theba* shells. The isolated colony at Marjorie Bay presumably derived from a surviving remnant of the formerly extended Cape Vlaming colony. The extinction of *Theba* in the area south of Gun Hill could also be due to fire, but we have been unable to document a recent fire in that area. In both of these areas, the present vegetation is largely *Acanthocarpus*, so apparently is suitable for *Theba*.

(c) Dispersal

On the mainland dispersal of *Theba* has been due largely to human activity, as indicated by the many colonies found at isolated coastal locations frequented by motorists. The same effect is seen on Rottnest, where the colonies at the lighthouse, Cape Vlaming, and Stark Bay each centre on military encampments. However, subsequent expansion appears not to

have been through human assistance. The only case where the present distribution is along a road verge is that connecting the lighthouse and eastern zones. However, in this case, the habitat on either side of the road is apparently unsuitable: a plantation on the north, and *Olearia* on the south. Consequently, the important limits of dispersal have been those of the snails themselves.

RATES OF COLONISATION

The introduction and subsequent spread of *Theba* on Rottnest allows measurement of the ability of this snail to colonise available habitats. For each area of colonisation, we measured the distance of expansion in the eight major compass directions during each between-census interval. The average of these values was then expressed as expansion per year. As we are interested here in the ability of the snails to disperse, rather than in barriers to dispersal, we excluded measurements terminated by shoreline or other unsuitable habitat (as indicated by stable boundaries between censuses).

TABLE 2.—RATE OF SPREAD (METRES/YEAR) OF *THEBA PISANA* THROUGH FAVOURABLE HABITAT BETWEEN SURVEY TIMES. DATA PRIOR TO 1978 ARE CALCULATED FROM SERVENTY AND STORR (1959).

	1925 to 1936	1936 to 1947	1947 to 1958	1958 to 1978
Eastern Zone	22	29	22	*
Lighthouse	—	—	15	22
Cape Vlaming	—	—	22	*
Stark Bay	—	—	—	16

* Excluded because of environmental limitations to expansion.

The measurements are remarkably consistent (Table 2), yielding a mean (± standard error) linear expansion of 21 (± 2.6) metres/year. This value is considerably higher than one might expect from estimates of movement of 4.7 metres/year by *T. pisana* in South African dunes (Hickson, 1972). The latter value was based on movements of adult snails during summer. The advantage of the data for Rottnest is the inclusion of all means of dispersal over long time intervals.

The areas where the historical rate of expansion is most likely to continue are from the lighthouse and Stark Bay colonies, as the frontiers are largely *Acanthocarpus* and *Asphodelus*. These colonies are presently separated by approximately 450 metres. Consequently, we would anticipate fusion of the two colonies in about 10 years. Expansion from the Cape Vlaming and Marjorie Bay colonies also seems likely.

Although from the initial rapid spread of *Theba* on Rottnest one might predict occupation of the entire island, this now seems unlikely. The apparent inability of *Theba* to colonise dense *Olearia* and other dense cover indicates that the stable boundaries already discovered are likely to remain. The maturation of plantation areas will further dissect the areas occupied. Moreover in many parts of the island *Theba* are very sparse (Perry, 1978), even where they were once abundant. Although the reason is not clear, this low density may prevent expansion of the colonised area.

This survey began as a field exercise for Zoology 200 students at the University of Western Australia; we thank G. Armstrong, J. Burt, V. Cullen, C. David, A. Gray, C. Harwood, P. Middleton, L. Sorokin, T. Treloar for their assistance. D. Edward, G. and M. Lewis also helped with the survey. The Biological Research Station provided accommodation.

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ANOTHER DISCOVERY OF *ZYGOMATURUS* FROM THE MURCHISON RIVER, WESTERN AUSTRALIA

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In late September 1978, Mr John White of Mullewa reported to the Western Australian Museum that he had discovered bone fragments eroding out of the banks of the Murchison River. The bones were found in the same area where, in the late 1950's, a complete mandible of *Zygomaturus trilobus* was found by H. White (Merrilees, 1968) and a large scapula and other fragments were found by J. White. Following this report, G. Kendrick of the Palaeontology Department and W. Ferguson and myself of the Archaeology Department of the Western Australian Museum investigated the site.

The fossil site is located in the bed of the Murchison River on Billabalong Station about 20 m downstream from the road bridge on the Mullewa-Gascoyne Junction road, 120 km north of Mullewa. The bones were embedded on a one metre thick deposit of coarse brown sandstone which contains some clay and has irregular silicification, particularly in its top 10 cm. Silicified plant fragments are abundant throughout the unit.

Overlying the fossil bearing unit is a silica band 2-3 cm thick, most easily visible on the downstream side of the bridge, and above this there is a coarse brown friable sandstone about 25 cm thick overlain by a grey-brown silcrete band 10-15 cm thick. All these sediments underlie a modern red alluvium and all are now cut through by the Murchison River.

The outline of the lower jaw of a large diprotodontid could easily be recognised among the group of bone fragments shown to us by Mr John White and in addition to this group, two other bone fragments were found, each within a few metres of the first group. All the bones were in an extremely worn and weathered condition and to prevent their further deterioration it was decided to excavate the exposed fragments.

Because the surface of the sediments in which the bones were embedded was so hard, the fossils were excavated in 'blocks' of sediment and this remaining sediment was removed at the museum. The two blocks from the main group of fossils revealed several more bone fragments than had been visible from the surface, but only four of these were identifiable and most were only scraps of bone.

All four of the identifiable specimens are attributable to the genus *Zygomaturus*. These are a left lower permanent premolar (catalogued in the Western Australian Museum palaeontology collection as 79.1.13), a molar fragment (79.1.14), a fragment of lower jaw containing a complete left lower incisor and an incomplete right lower incisor (79.1.12) and the lingual side of a left dentary containing fragments of the second, third and fourth molars and including the condyle and coronoid process (79.1.11). Despite the number of fragments it is possible that only one individual is represented. A few of the other fragments of bone also represent a large diprotodontid but these fragments were too incomplete to assign to genus.

The fragments of *Zygomaturus* do not appear to differ in size or form from specimens of *Zygomaturus trilobus* in the W.A. Museum palaeontology collection (including those found at the Murchison River previously) and it is probable that the new specimens are also referable to *Z. trilobus*.

All the bone excavated by us in October appeared to be in the same